Bayesian analysis of the detection performance of the Lightning Imaging Sensors

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Motivation

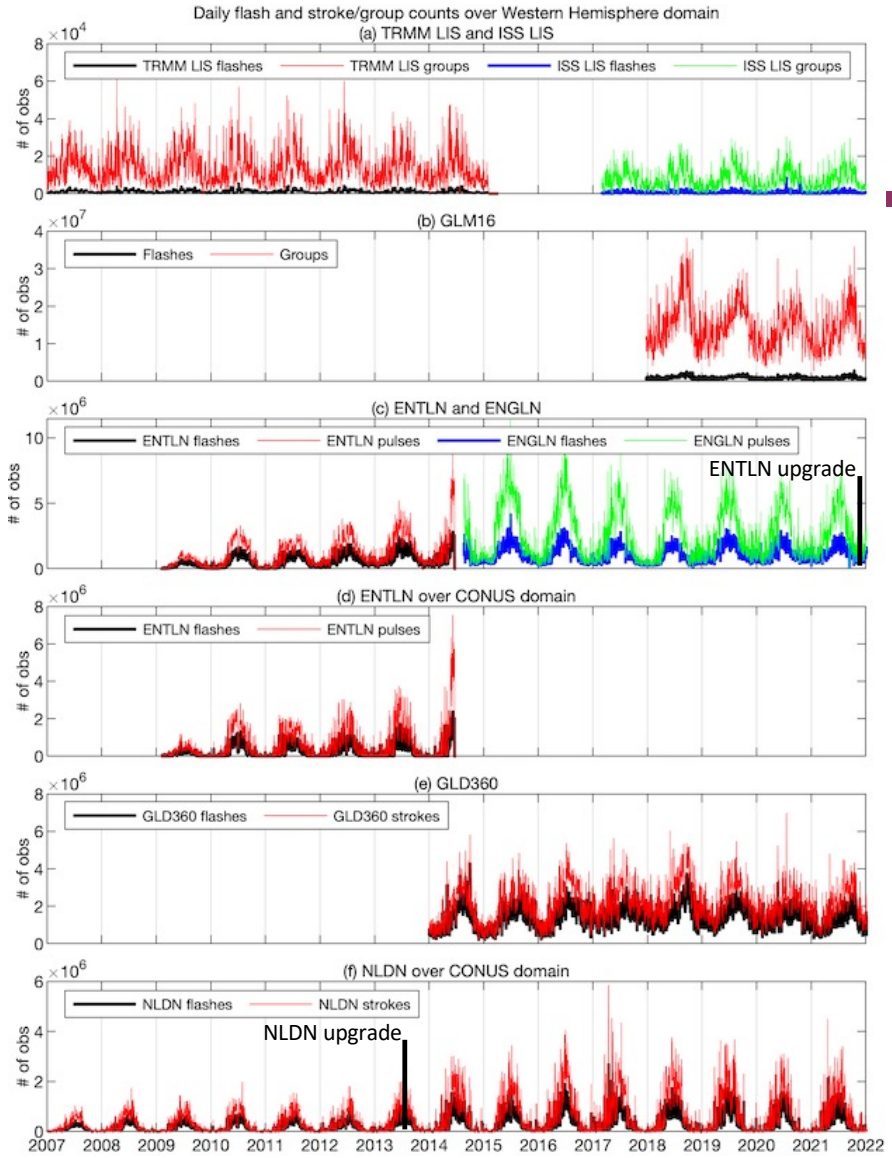
- Lightning Imaging Sensors aboard the Tropical Rainfall Measuring Mission satellite (TRMM LIS, 1998-2015) and International Space Station (ISS LIS, 2017-present) have provided over two decades of lightning observations over the global tropics, and now mid-latitudes
- The Goal: Generate a LIS climatological record and combine LIS data with lightning detections from other sensors/networks
- The Challenge:
  - Necessity of quantifying the detection performance of LIS and other lightning sensors/networks
  - TRMM LIS and ISS LIS did not overlap, and reference networks have evolved
- Outstanding Question: How can we quantify the detection performance of both LIS instruments and other reference sensors/networks?

Bayesian methodology

- Detection efficiency (DE) = % of true lightning flashes a sensor detects
- Most studies calculate relative DE
  - Probability that sensor A detects a discharge given that sensor B detected the same discharge
  - Assumes that the reference sensor (B) detects all lightning
- Bitzer et al. (2016) introduced a Bayesian method for absolute DE (ADE)
  - Does not assume that either sensor detects all lightning
  - Calculated with respect to the larger universe of detected lightning
  - Provides an upper estimate of ADE for each sensor being analyzed
- Bitzer and Burchfield (2016) applied the Bayesian method to ground network pulses/strokes: ENTLN (56.8% ADE), GLD360/NLDN (59.8%), and WWLLN (7.9%)

Lightning data available for Bayesian analysis

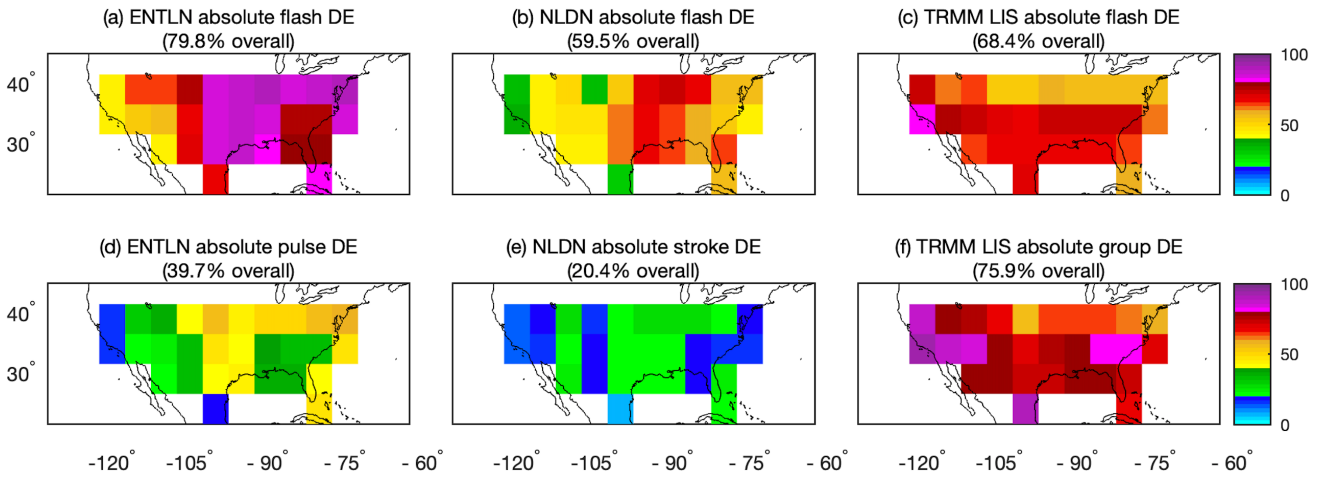
Source	Lightning data	Time period	Domain
Satellite optical sensors			
GLM-16 *Geostationary Lightning Mapper on GOES-16*	Event, group, flash	Dec 2017-Present	Western Hemisphere
ISS LIS *Lightning Imaging Sensor on the International Space Station*		Mar 2017-Present	Global tropics + mid-latitudes
TRMM LIS *Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission*		Jan 1998-Apr 2015	Global tropics
Ground-based RF networks			
ENGLN *Earth Networks Global Lightning Network*	Pulse	Sep 2014-Present	Global
ENTLN *Earth Networks Total Lightning Network*		Feb 2009-Jun 2014	Global
GLD360 *Global Lightning Dataset 360*	Stroke	Jan 2014-Present	Global, but available only for Western Hemisphere
NLDN *National Lightning Detection Network*		Jan 2007-Present	CONUS



Lightning trends

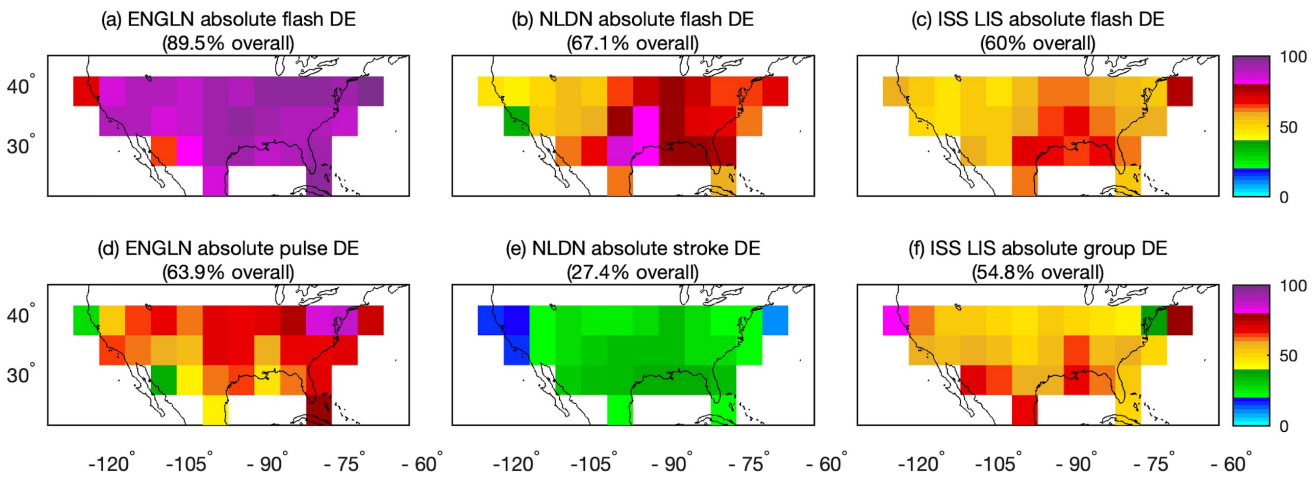
- Ground-based stroke and pulse data are clustered into flashes using same parameters as for LIS
  - ±330 ms, 5.5 km
- Ground-based detections trend upward with additional sensors and improved detection methods (Murphy et al. 2014; Zhu et al. 2022)
- ~15% decrease in daily LIS flash counts from TRMM to ISS era
  - ISS spends less time over the tropics
  - ISS LIS may be less sensitive
  - Missing ISS LIS data packets (1/min)
  - Factors relating to ISS platform

CONUS – TRMM LIS era



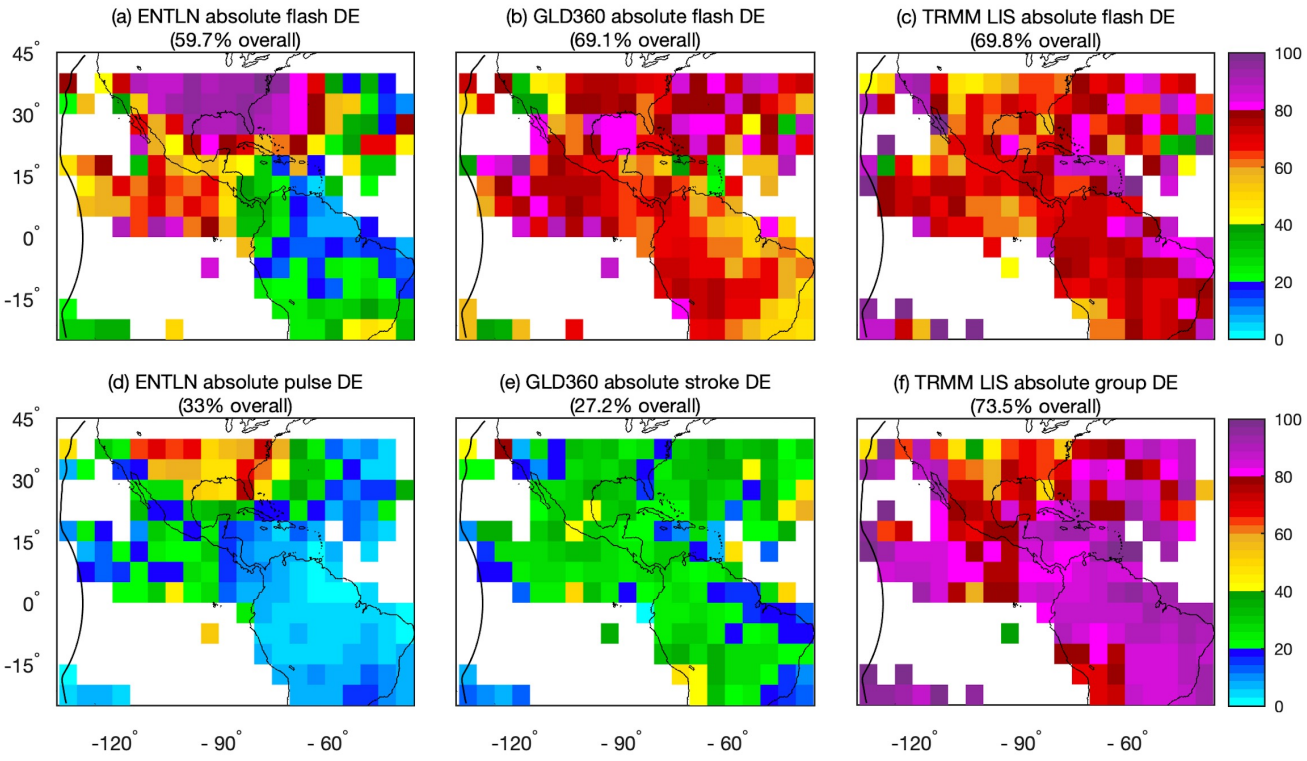
- Comparison: ENTLN vs NLDN vs TRMM LIS (~5.5-year overlap period)
- Highest flash ADE: ENTLN (80%) followed by TRMM LIS (68%) and NLDN (60%)
- Ground networks have higher ADE over the central and eastern US
- TRMM LIS geographic pattern is more spatially consistent

CONUS – ISS LIS era



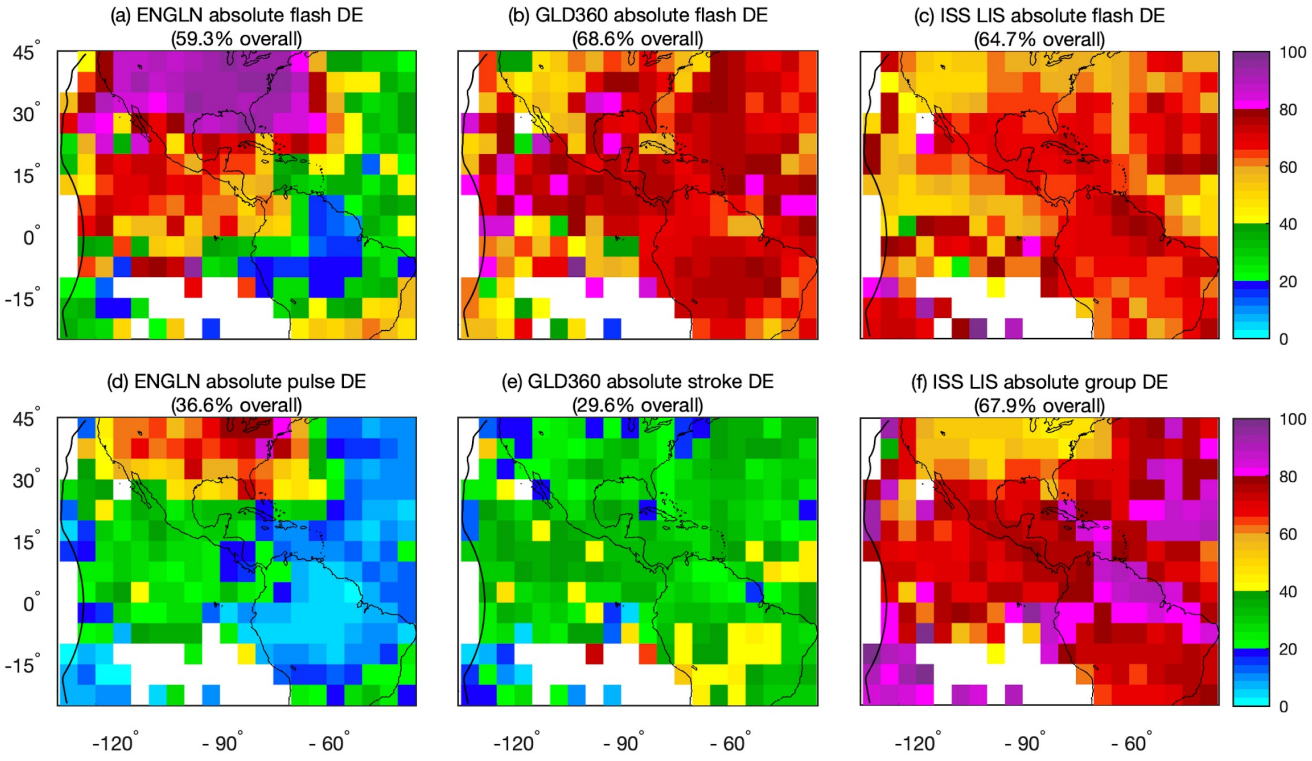
- Comparison: ENGLN vs NLDN vs ISS LIS (~5.5-year overlap period)
- Highest flash ADE: ENGLN (90%) followed by NLDN (67%) and ISS LIS (60%)
- Decrease in ISS LIS ADE from the TRMM era: 8% (flash) and 21% (group)
- Further investigation needed into disparate performance over the western US

Western Hemisphere – TRMM LIS era



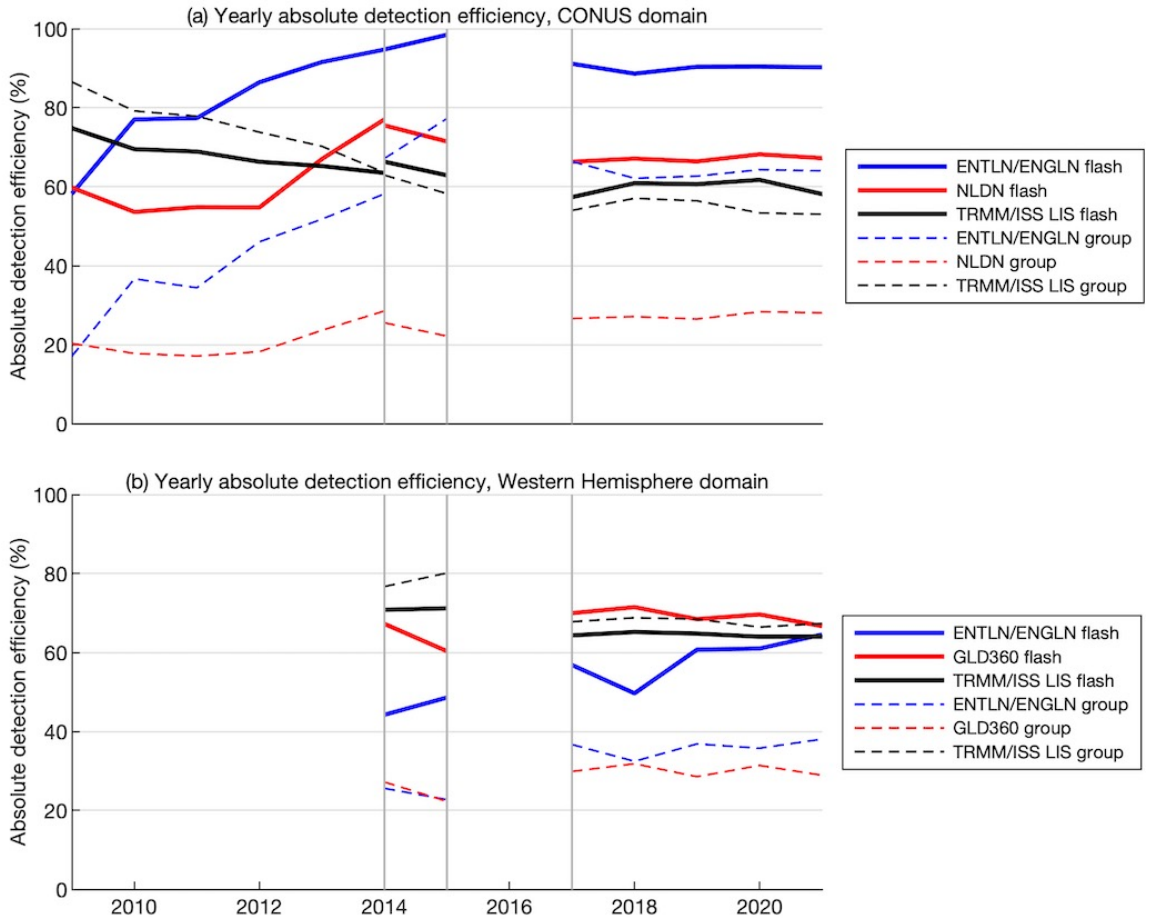
- Comparison: ENTLN vs GLD360 vs TRMM LIS (6-month overlap)
- Highest flash ADE: TRMM LIS (70%) followed by GLD360 (69%) and ENTLN (60%)
- ENTLN exhibits the most spatial variation, with high ADE over CONUS
- TRMM LIS and GLD360 are more spatially uniform

Western Hemisphere – ISS LIS era



- Comparison: ENGLN vs GLD360 vs ISS LIS (~5.5-year overlap period)
- Highest flash ADE: GLD360 (69%) followed by ISS LIS (65%) and ENGLN (59%)
- Decrease in ISS LIS ADE: 5% (flash) and 6% (group)
- ENGLN continues to perform best in regions with dense sensor network
- GLD360 has highest flash ADE but lowest stroke ADE

Absolute detection efficiency trends



- ENTLN flash ADE increased by >30% and NLDN by >15% during the TRMM era
- ADE for all sensors has been more or less consistent during the ISS LIS era
- Decline in TRMM LIS ADE likely primarily due to substantial improvement in reference network performance
- Actual decrease in performance from last two years of TRMM LIS to ISS LIS is ~4-5%

Conclusions

- Comparing performance of TRMM LIS and ISS LIS is complicated because they did not overlap, and reference networks have evolved
- Bayesian technique produces estimates of the upper limit of absolute detection efficiency for LIS sensors and reference sensors/networks
- ENGLN exhibits the highest flash and stroke ADE over CONUS
- GLD360 exhibits more consistent spatial coverage, with the highest flash ADE during the ISS LIS era
- Year-by-year analysis suggests that ISS LIS flash ADE is likely 4-5% lower than TRMM LIS
- Taking into account GLM-16 comparisons (not shown), the most representative ISS LIS ADE is 61-65% (flash) and 57-68% (group/stroke)

Thank You!

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